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SIDE LOBE LEVEL OPTIMISATION OF CIRCULAR MICROSTRIP ARRAY ANTENNA USING GENETIC ALGORITHM

K. KARUNA KUMARI[1] & P. V. SRIDEVI[2]

[1]Associate Professor, Department of ECE, GITAM University, Visakhapatnam, Andhra Pradesh, India

[2]Associate Professor, Department of ECE, Andhra University, Visakhapatnam, Andhra Pradesh, India

ABSTRACT

In the recent years the development in communication systems requires the development of low cost, minimal weight, low profile antennas that are capable of maintaining high performance over a wide spectrum of frequencies. This technological trend has focused much effort into the design of a micro strip patch antennas. The popularity of micro strip antennas are increasing day by day because of ease of analysis and fabrication, and their attractive radiation characteristics. So the micro strip Antenna are very useful & essential device for effective wireless communication. This paper focuses on the application of binary coded Genetic Algorithm (BGA) which is applied to the Circular Patch Microstrip antenna with linear and non linear (Dolph-Chebyshev) arrays. The cost function of Genetic Algorithm(GA) is maximum reduction in side lobe level of the radiation pattern of the antenna .The genetic algorithm finds the optimum amplitude current excitations co-efficient of the antenna array elements to provide the radiation pattern with maximum reduction in the side lobe level and also achieved the minimum possible null to null beam width, the resultant radiation patterns for both before GA and after GA of Microstrip array are compared. The Radiation patterns are presented for different number of elements. All the simulated results are obtained by using MATLAB software.

KEYWORDS: Microstrip Circular Patch Antenna, Genetic Algorithms, Linear Array Antenna, Dolph-Chebyshev Array, MATLAB Software

INTRODUCTION

Theory of Microstrip Antenna

In this paper circular Microstrip circular patch antenna used as an unit element. Microstrip patch antenna is very simple in the construction using a conventional fabrication technique. These antennas are used for the widest and most demanding applications because of dual characteristics, circular polarizations, dual frequency operation, frequency agility, broad band width, feed line flexibility, beam scanning can be easily obtained from these patch antennas. Structure of Micro strip circular Patch Antenna as shown in figure 1. four basic parts of antenna are 1) The patch 2) Dielectric Substrate 3) Ground Plane 4) Feed Line

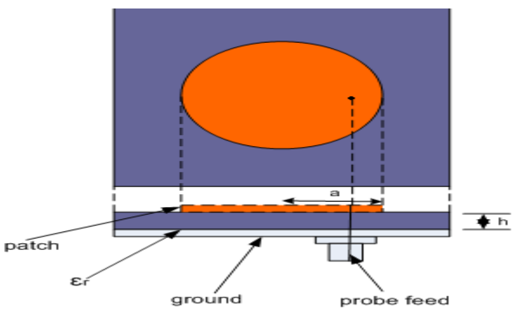

Figure 1: Micro Strip Circular Patch Antenna

Physical Radius of the Circular Patch equation given by

$$a = \frac{F}{\left(1+\frac{2h}{\prod \varepsilon_r F}\left[\ln\left(\frac{\prod F}{2h}\right)+1.7726\right]\right)^{1/2}}$$

a=Physical Radius of the Circular patch

h=Height of the substrate

f_r=Resonant frequency of the antenna

ε_r = Dielectric constant of substrate

$$F = \frac{8.791X10^9}{f_r\sqrt{\varepsilon_r}}$$

The effective radius of the antenna is obtained with equation given by

$$a_e = a\left[1+\frac{2h}{\prod a\varepsilon_r}\left(\ln\frac{\prod a}{2h}+1.7726\right)\right]^{1/2}$$

The dielectric material , ε_r is commonly known as substrate. The dielectric constant for the materials range from 2.1 to ≈ 12.

Equivalent Current Densities and Fields Radiated for Micro Strip Circular Patch Antenna

Applying the Equivalence principle to the circumferential wall of the cavity, the equivalent magnetic current density can be obtained and assuming a TM11z mode the field distribution under the patch. The evaluation of equation of the electrical equivalent edge of the disk and magnetic current density can be expressed as

$$M_a = -2\hat{n}XE_a \,_{\rho' = a_e}$$

Since the thickness of the substrate is very small, the filamentary magnetic current becomes

$$I_m = hM_a = \hat{a}_0 2hE_0 J_1(ka_e)\cos\phi'$$

$$I_m = a_e 2V_0 \cos\phi'$$

Where $V_0 = hE_0 J_1(Ka_e)$ at $\phi = 0$

The patch antenna can be treated as a circular loop and using the radiation equations the expression is given by

$$E_r = 0$$

$$E_\rho = \left(-jk_0 a_e V_0 e^{-jk\sigma r}/2r\right)[\cos\phi J_{02}]$$

$$E_\phi = \frac{\left(jk_0 a_e V_0 e^{-jk\sigma r}\right)}{2r}[\cos\theta \sin\phi J_{02}]$$

Then the field in the principal plane reduced to when E-plane $\phi = 0^0, 180^0, 0 \le \theta \le 180^0$

$$E_\rho = \frac{\left(jk_0 a_e V_0 e^{-jk\sigma r}\right)}{2r}[J_{02}]$$

$$E_\phi = 0$$

Also, H-plane ($\phi = 90^0, 270^0, 0 \le \theta \le 90^0$) are:

$$E_\phi = \frac{\left(jk_0 a_e V_0 e^{-jk\sigma r}\right)}{2r}[\cos\phi J_{02}]$$

Where $J'_{02} = J_0(k_0 a_e \sin\theta) - J_2(k_0 a_e \sin\theta) \quad J_{02} = J_0(k_0 a_e \sin\theta) + J_2(k_0 a_e \sin\theta)$

$$k_0 = \frac{2\Pi}{\lambda}$$

PROBLEM FORMULATION

This paper consider with two arrays 1.Uniform Linear array antenna 2. Dolph-Tschebyscheff Array.

Uniform N-Element Linear Array

(Uniform spacing, uniform amplitude, linear phase progression)

A uniform array is defined by uniformly-spaced identical elements of equal magnitude with a linearly progressive phase from element to element.

$$\phi_1 = 0 \; \phi_2 = \alpha \; \phi_3 = 2\alpha \quad \ldots \quad \phi_N = (N-1)\alpha$$

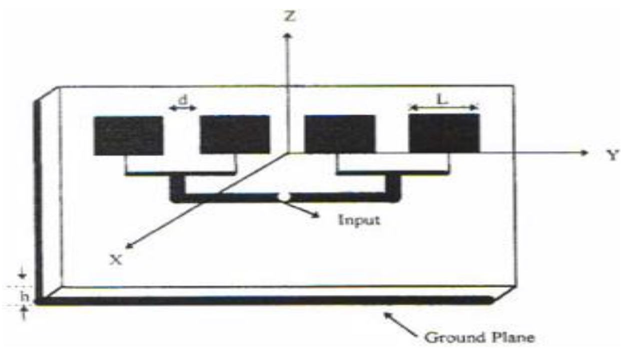

Figure 2: Micro Strip Antenna Arrays

Design Equations of Uniform Linear Array

Inserting this linear phase progression into the formula for the general N element of array gives

$$AF = \frac{e^{jN\psi} - 1}{e^{j\psi} - 1} = \frac{e^{jN\frac{\psi}{2}}}{e^{\frac{j\psi}{2}}} \frac{e^{jN\frac{\psi}{2}} - e^{-jN\frac{\psi}{2}}}{e^{\frac{j\psi}{2}} - e^{-j\frac{\psi}{2}}} = e^{j(N-1)\frac{\psi}{2}} \frac{\sin\left(\frac{N\psi}{2}\right)}{\sin\left(\frac{\psi}{2}\right)}$$

Where $\psi = \alpha + kd\cos\theta$

N=number of elements

The function Ψ is defined as the array phase function and is a function of the element spacing, phase shift, frequency and elevation angle.

If the position of the array is shifted so that the center of the array is located at the origin, this phase term goes away. The array factor(AF) then becomes

$$AF = \frac{\sin\left(\frac{N\psi}{2}\right)}{\sin\left(\frac{\psi}{2}\right)}$$

Dolph-Tschebyscheff Array

(Uniform spacing, but non uniform amplitude distribution):

Dolph-Tschebyscheff Array is primarily a compromise between uniform and binomial arrays. Its excitation coefficients are related to Tschebyscheff polynomials. A Dolph-Tschebyscheff array with no side lobes (or side lobes of −∞ dB) reduces to the binomial design.

Design Equations of Non Uniform (Dolph-Tschebyschef) Array

$$P = 2M + 1(odd)$$

$$(E)_P = E_{M+1} + \ldots.. + E_2 + E_1 + E_1^{'} + E_2^{'} + \ldots. + E_{M+1}$$
$$= 2I_0E_0\{a_1 + a_2\cos(kd\cos\theta) + a_3\cos(2kd\cos\theta) + ..a_{M+1}\cos(Mkd\cos\theta)\}$$

$$(AF)_P = \sum_{n=1}^{M+1} a_n \cos[2(n-1)\frac{\prod d}{\lambda}\cos = \sum_{n-1}^{M+1} a_n \cos[2(n-1)u]$$

$$u = \frac{\prod d}{\lambda}\cos\theta$$

$$P = 2M(even)$$

$$(E)_P = E_M + \ldots + E_2 + E_1 + E_1^{'} + E_2^{'} + \ldots + E_M$$

$$= 2I_0E_0\{a_1\cos(\frac{1}{2}kd\cos\theta) + a_2\cos(\frac{3}{2}kd\cos\theta) + ..a_M\cos(\frac{2M-1}{2}kd\cos\theta)\}$$

$$(AF)_P = \sum_{n=1}^{M} a_n \cos[2n-1)\frac{\prod d}{\lambda}\cos\theta] = \sum_{n-1}^{M} a_n \cos[(2n-1)u]$$

MICROSTRIP PATCH ANTENNA ARRAY

Microstrip antennas are used not only as single element but are very popular in arrays. Arrays are very versatile and are used to synthesize a required pattern that cannot be achieved with a single element. Arrays increase the directivity, and perform various other functions which would be difficult with any one single element. In this paper presenting the two different arrays. 1. linear array antenna 2. A Dolph-Tschebyscheff array. The main objective of this paper is to reduce the side lobe level of the antenna array. Radiation pattern of the antenna has not only the main beam but also side lobes. Most of the power is confined into main beam which provides the coverage into desired area. Some of the power is also distributed in the side lobes that are nothing but wastage of transmitting power. If the level of side lobe is high, large amount of transmitting power is wastage. For efficient use of transmitting power, it is required to reduce the side lobe level. Side lobe level reduction can be obtained by controlling the following antenna parameters: 1) the amplitude current excitations 2) the phase excitations and 3) the complex weights. Various analytical and numerical methods have been used to optimize the side lobe level at desired level relative to main beam.

Resultant Pattern of Microstrip Antenna with Linear Array Factor is given by

$E_{total}(\Theta)$=[E(Microstrip _circular patch antenna)] x [linear array-factor]

$$E_{total}(\theta) = \left(\frac{\left(jk_0 a_e V_0 e^{-jk\sigma r}\right)}{2r} [\cos\phi J_{02}] \right) \times \left[\frac{\sin\left(\frac{N\psi}{2}\right)}{\sin\left(\frac{\psi}{2}\right)} \right]$$

Where

$$J'_{02} = J_0(k_0 a_e \sin\theta) - J_2(k_0 a_e \sin\theta) \qquad J_{02} = J_0(k_0 a_e \sin\theta) + J_2(k_0 a_e \sin\theta)$$

Resultant Pattern of Microstrip Antenna with Dolph-Tschebyscheff Array is given by

$E_{total}(\Theta)$=[E(Microstrip _circular patch antenna)] x [Dolph-Tschebyscheff Array -factor]

$$E_{total}(\theta) = \left(\frac{\left(jk_0 a_e V_0 e^{-jk\sigma r}\right)}{2r} [\cos\phi J_{02}] \right) \times \left[\sum_{n-1}^{M+1} a_n \cos[2(n-1)u] \right]$$

$$u = \frac{\Pi d}{\lambda} \cos\theta$$

Normalized power pattern, P(θ) in dB can be expressed as follows

$$P(\theta) = 20\log\left(\frac{|E_{total}(\theta)|}{\left|E_{total}(\theta)_{\max}\right|} \right)$$

GENETIC ALGORITHM

The Genetic Algorithm (GA) is an optimization and global search technique based on the mechanics of natural selection and natural genetics. A Genetic Algorithm allows a population composed of many individuals to involve under specified selection rules to a state that minimizes the cost function. This optimization algorithm is more powerful for problems with more number of variables and local minima. GA is very efficient in exploring the entire search space or the solution space, which is large and complex. The Genetic algorithm is implemented using computer simulation. Genetic Algorithm may be represented as shown in Figure 3.

In computer algorithm, a chromosome is an array of genes, a number of chromosomes make up one population. The chromosomes are generated randomly in the selected space. Each chromosome has an associated fitness function, assigning a relative merit to that chromosome. The algorithm begins with a large list of random chromosomes. Fitness functions are evaluated for each chromosome. The chromosomes are ranked from the best-fit to the least-fit, according to their respective fitness functions. Unacceptable chromosomes are discarded, leaving a superior species-subset of an original list, which is the process of selection. Genes that survive become parents, by crossing over some of their genetic material to produce two new offspring. The parents reproduce enough to offset the discarded chromosomes. Thus, the total number of chromosomes remains constant after every iteration. Mutations cause small random changes in a chromosome. Fitness functions are evaluated for the offspring and mutated chromosome, and the process is repeated. The algorithm stops after a set number of iterations, or when an acceptable solution is obtained.

In the genetic algorithm, initial chromosomes are combination of random chromosome and amplitude excitations of linear array instead of all random chromosomes. The halves of the chromosome are discarded and new half of

chromosomes are generated from parents chromosome which are best fits to fitness function. The cost function is the maximum side lobe level for the antenna pattern.

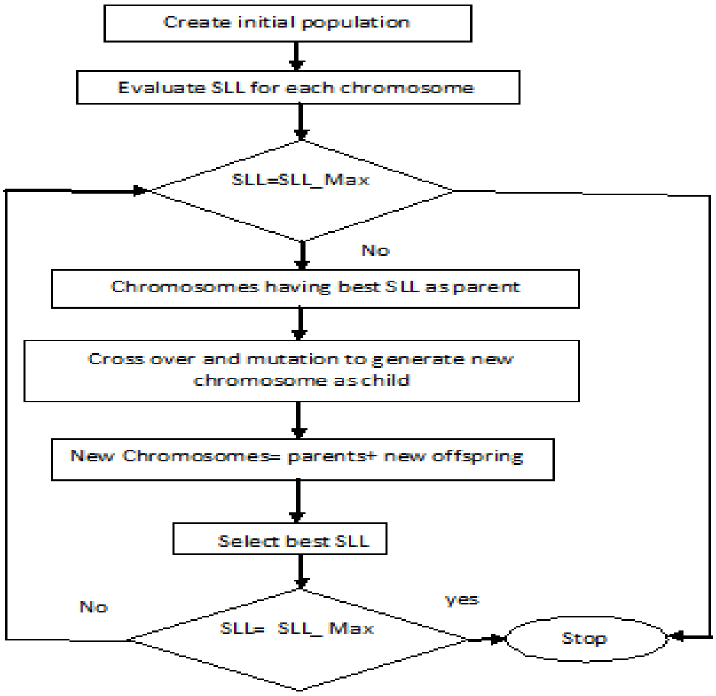

Figure 3: Genetic Algorithm for Optimization of Side Lobe Level

RESULTS &DISCUSSIONS

This paper consider with circular patch Microstrip antenna with uniform linear and Dolph-Tscheby scheff arrays are used. The elements of the array are equally spaced with d = 0.25λ along the x-axis. The resultant Radiation pattern of Microstrip antenna array is computed at frequency of 2.5 GHz(s-band) with effective dielectric constant 2.23(Duroid), Height of dielectric material 0.15cm , Physical Radius of the Patch 2.2549cm, Effective Radius of the Patch 2.3582cm. Radiation patterns of Microstrip antenna with linear array before and after Genetic Algorithm applied with 20,50,100 elements as shown in figures. Before GA First side lobe level of -13.34db is obtained. For the same linear array after GA First side lobe level of -31db is achieved. All the simulated results are obtained by using MAT lab soft ware.

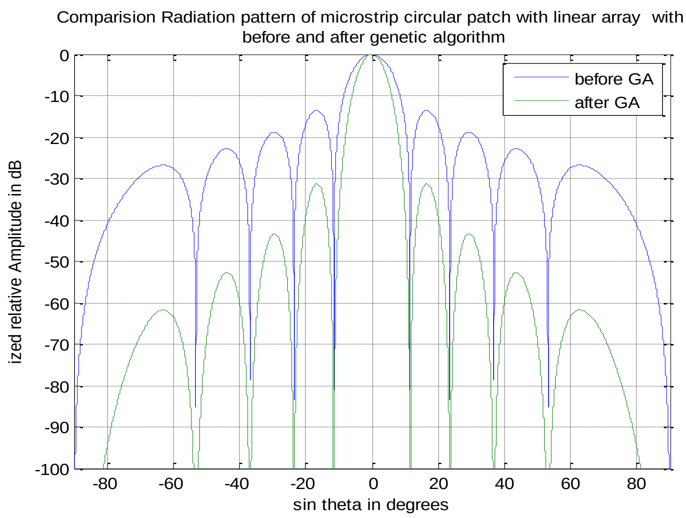

Figure 4: Comparison of Radiation Patterns of Linear Array and Linear Array with GA of 20 Elements. Without GA SLL= -13.36dB; With GA SLL= -31dB

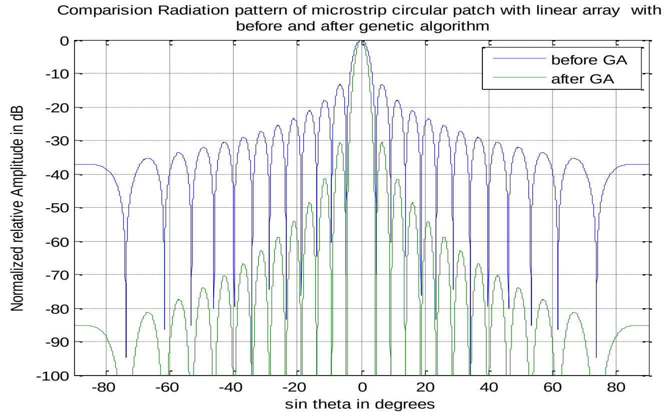

Figure 5: Comparison of Radiation Patterns of Linear Array and Linear Array with GA of 50 Elements. Without GA SLL= -13.36dB; With GA SLL= -31dB

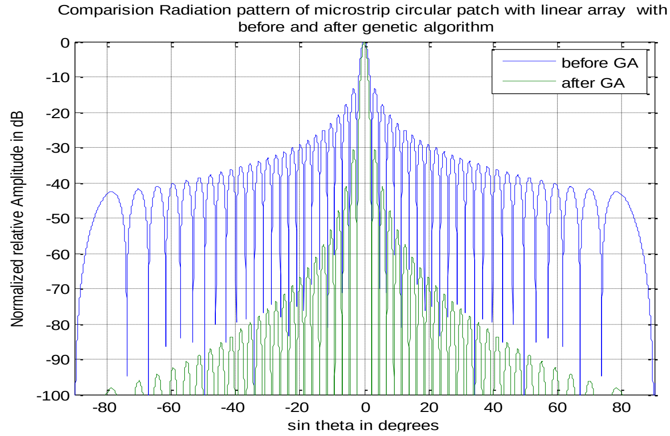

Figure 6: Comparison of Radiation Patterns of Linear Array and Linear Array with GA of 100 Elements. Without GA SLL= -13.36db; With GA SLL= -31db

Table 1: Parameter Comparison of Microstrip Antenna with Uniform Linear Array

No .of Elements of Microstrip Antenna with Linear Array	FPBW in Degrees		HPBW in Degrees		Side Lobe Level(SLL) in dBs	
	Before GA	After GA	Before GA	After GA	Before GA	After GA
10	46.4	46.4	20	13.4	-13.36	-31
20	23.5	22.75	10	6.76	-13.36	-31
50	11	10	4	2.2	-13.36	-31
100	4.58	4.5	2.16	1.36	-13.36	-31

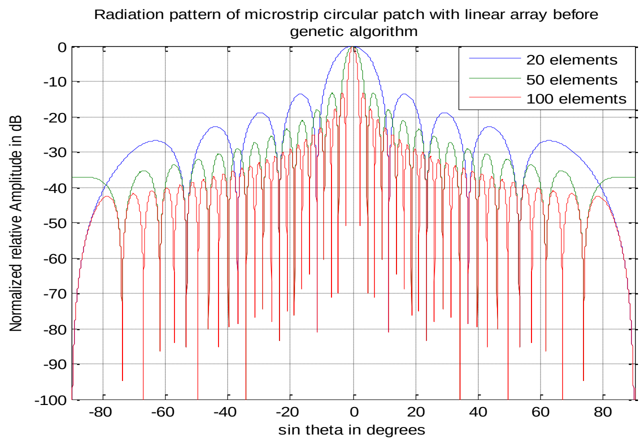

Figure 7: Comparison of Radiation Patterns of Linear Array with 20,50,100 Elements. Without Applying GA, the SLL= -13.36dB

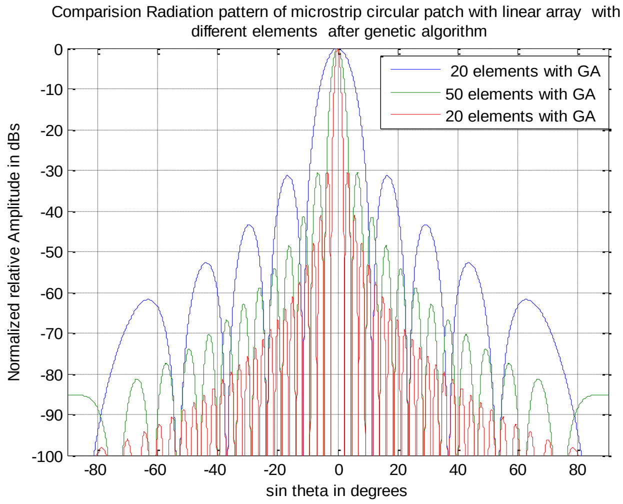

Figure 8: Comparison of Radiation Patterns of Linear Array with 20, 50,100 Elements. With Applying GA, the SLL=-31 dB

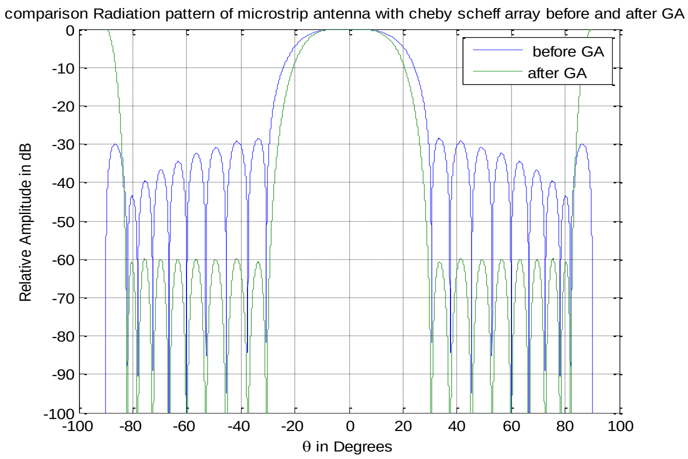

Figure 9: Comparison of Radiation Patterns of Tscheby Scheff Array with 10 Elements. With GA the SLL=-60.75dB, Without GA SLL= -28dB

Table 2: Parameter Comparison of Microstrip Antenna with Tscheby Scheff Array

No. of Elements of Microstrip Antenna with Tscheby Scheff Array	FPBW in Degrees		HPBW in Degrees		Side Lobe Level(SLL) in dBs	
	Before GA	After GA	Before GA	After GA	Before GA	After GA
10	61.62	59.88	35.8	30.88	-28	-60.75

CONCLUSIONS

From the Results, we conclude that the Genetic Algorithm performs better than the analytic technique, linear array and Tscheby scheff array. The side lobe level obtained with GA for linear array is less than -31 dB and Tscheby scheff array is less than -60.75dB and also reduces the beam width. The application of Genetic algorithm for reduction in the side lobe level and as well as beam width is found to be useful in many wireless communications because the most of the power is confined into main beam which provides the coverage into desired area. Some of the power is also distributed in the side lobes that are nothing but wastage of transmitting power. If the level of side lobe is high, large amount of transmitting power is wastage. For efficient use of transmitting power, it is required to reduce the side lobe level to minimize the amount of transmitting power.

REFERENCES

1. C. A. Balanis, ‘Antenna Theory’, John Wiley, ‘*Analysis and design’*, 2nd Ed., 1997.
2. Ramesh G, Prakash B, Inder B, and Ittipiboon A. (2001) *Microstrip antenna design* handbook, Artech House.
3. G. S. N. Raju, Antennas and wave propagation, Pearson Education,2005
4. K. Karuna Kumari, Dr. P. V. Sridevi “*Performance Evaluation of Circular Microstrip Patch antenna array with different Dielectric substrate” International journal of Electronics and Communication Engineering &Technology (IJECET)*, 4(1), 236 - 249.(Feb 2013)
5. C. L. Dolph, *A current distribution for broadside arrays which optimizes the relationship between beam width and side-lobe level*, Proc. IRE 34:335-348 (June 1946).
6. R. L. Haupt, “*Thinned arrays using genetic algorithm*”, IEEE Transaction on Antenna and Propagation, Vol.12 Issue 7, pp 993-999 July1994.
7. R. L. Haupt,. “*Introduction to Genetic Algorithms for Electromagnetics”, IEEE Antenna and propagation Magazine*. Vol. 37. pp. 7-15. 1995.
8. Orchard H. J., R.S. Elliot,, and Steen G.J. ‘*Optimizing the synthesis of shaped beam antenna patterns*’, IEE Proc., Pt. H, pp. 63-68, 1985.
9. D. Marcano, F. Duran, “*Synthesis of Antenna Arrays Using Genetic Algorithms”. IEEE Antenna and propagation* Magazine. Vol. 42. NO. 3. June 2000.
10. M.A.Panduro, “*Design of Non-Uniform Linear Phased Arrays using Genetic Algorithms To Provide Maximum Interference Reduction Capability in a Wireless Communication System*”, Journal of the Chinese Institute of Engineers,Vol.29 No.7,pp 1195-1201(2006).
11. R.L.Haupt, “*Synthesizing low sidelobe quantized amplitude and phase tapers for linear arrays using genetic algorithms*, Proc Inte.Conf. Electromagnetics in Advanced Application, Torino, Italy, pp 221-224 Sept.1995.
12. Keyur Patel and Rizwan Alad” *Side Lobe Level Optimization of Planar Phased Array Antenna using Genetic Algorithm*” International Journal of Emerging Trends in Electrical and Electronics (IJETEE) Vol. 2, Issue. 4, April-2013.
13. V.Rajya Lakshmi, G. S. N. Raju “*Synthesis Of Linear Antenna Arrays Using Array Designer and Genetic Algorithm*” International Journal of Advanced Engineering Sciences and Technologies. Vol No. 9, Issue No. 1, 044 – 048
14. S. A. Mitilineos, C A, Papagianni. G.. I. Verikaki. C. N. Capsalis, “*Design of Switched Beam Planar Arrays Using the Method of Genetic Algorithms*”, Progress In Electromagnetics Research. PIER 46. 105-126. 2004.
15. Cheng D K, “*Optimization techniques for antenna arrays*”, Proceedings for IEEE, vol.59 (12), 1988, pp. 1664-1674.